Using 2.4 GHz Radio Module for Transmitting Spirometers Data: Human Safety Testing

Serhiy Batachenko, Roman Tomashevskyi, Vadim Makarov

Industrial and Biomedical Electronics Department,
National Technical University
"Kharkiv Polytechnic Institute"
Kharkiv, Ukraine
batachenko9443@gmail.com, romiocat.khpi@gmail.com, vadim5580@gmail.com

I. INTRODUCTION

According to the World Health Organization WHO hardware methods of diagnosis and determination of the patient`s condition use a wired connection to the human body. Standard methods, which use outdated equipment, circulated in low-income counties, including Ukraine. In addition, each electrode or sensor connected to the monitor via a single cable. All these factors lead to carrying out uncomfortable procedure and make medical devices cumbersome. [1]

Nowadays, modern information technologies are taking an increasingly active place in all spheres of human activity. Medical instrument making is no exception. Continuous and discrete parameters of the condition of patient is necessary to monitor in real-time and it is not always possible in a hospital. However, the development of wireless technologies implements miniaturization of medical devices, as well as increase the level of comfort in procedures. Monitoring the patient's condition is now possible even when he is at home, on a walk or at work. Therefore, medical devices are equipped with a radio, Wi-Fi and Bluetooth technologies units, which passed a diagnostic check according to the data transmission standards. The parameters, which are obtained from the patient's body could be transferred at any distance. [2].

The involvement of wireless technologies in medicine allows concentrate all the necessary medical information in one database.

This approach allows:

- a sampling of the criteria of interest to identify the optimal treatment regimens;
- quickly and promptly update information on the patient's medical history;
- to select individual dosages of medicinal products, which contributes to increasing the effectiveness of treatment;
- reduce the cost of paper;
- make it impossible to lose patient's medical records;

automate the transfer of test results from laboratories to physicians.

The current level of development of special software for the work of physicians corresponds to the highest standards of data security placed on the World Wide Web, allowing online access to databases containing confidential patient data. [3]

In our research we are going to use spirometer with radio module nRF24L01 which passed testing according to the standard IEEE 802.15 – IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture and IEEE 802.15g – IEEE Standard for Local and metropolitan area networks-- Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 3: Physical Layer (PHY) Specifications for Low-Data- Rate, Wireless, Smart Metering Utility. [4]

That`s why, the aim of work is determining the effect of the radio module nRF24L01 on the condition of the patient according to IEEE Standard Std C95.1™-2005 – IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300GHz. [5]

II. GENERAL INFORMATION

Spirometer is a portable digital device designed for the study human respiratory function. [6] The main factor is to determine the effect of the radio module of spirometric devices on the condition of the patient.

Structural scheme of transmitting block has shown in Figure 1.

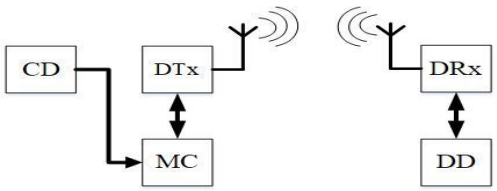

Fig. 1 Structural scheme of transmitting block

According to the standard IEEE Std C95.1™-2005 – IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300GHz.

should be tested the portable radio module nRF24L01 which shown in Figure 2. [7]

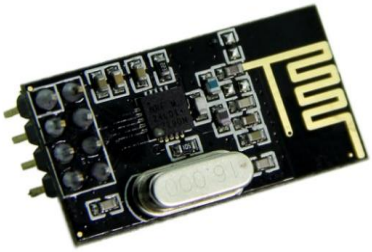

Fig. 2. NRF24L01

III. Results and Discussion

For the testing the radio module NRF24L01impact on the human body was created testing model, which shown in Figure 3.

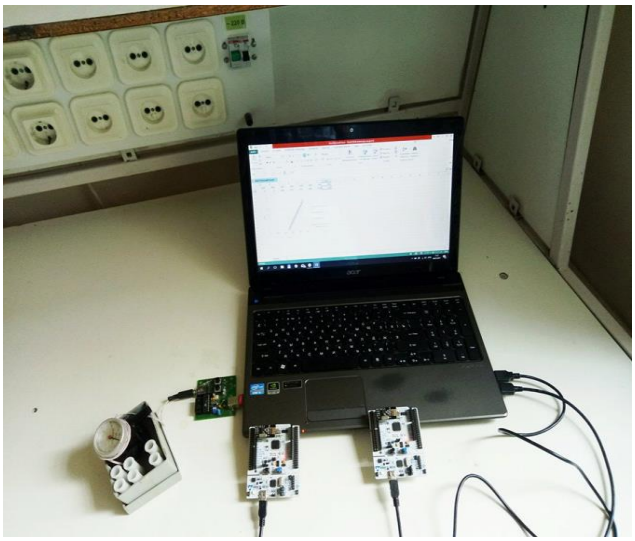

Fig. 3 Testing model

This working model included two microcontrollers STM32F411RE, two radio modules NRF24L01 and portable spirometer. It simulates the transfer data from spirometer via wireless.

We are using spectral microvoltmeter B6-10 to determine the level of the electromagnetic field, the energy flux density and the level of propagation of the electromagnetic field during our researches. [8]

The frequency range 3 kHz to 300 GHz belongs to extremely high-frequency radiation. Analysis of literature has shown that the level of the electromagnetic field of this frequency range must be less than 2,5 μW/cm^2. [9]

The results of measurements of the electromagnetic field of the radio nRF24L01 module in the energy saving mode are presented in Table 1.

TABLE I. The results of the experiments in the energy saving mode

Parameters	Values							
EMF, μW/cm^2	0.5	0.5	0.48	0.47	0.49	0.52	0.53	0.51
Time, s	15	30	45	60	75	90	105	120

According to the standards the level of electromagnetic field in the energy saving mode must be 0.5 μW/cm^2. Calculation of the relative error of the value, shown in formula (1).

$$\delta = \frac{|EMF_{et} - EMF_{exp}|}{EMF_{et}} * 100\% \quad (1)$$

where EMF_{et} – the reference value;

EMF_{exp} – the experimental value.

Histogram, which showing the level of relative error is shown in Figure 4.

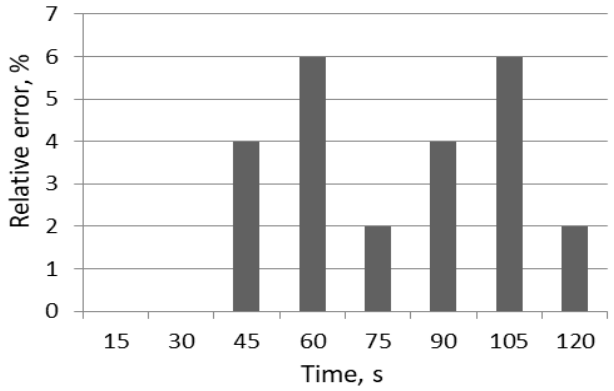

Fig. 4 The levels of relative error

The maximum reletive error of the deviations less than 6 %, which according to the requisition to radio module.

The results of measurements of the electromagnetic field of the radio nRF24L01 module in standard operating mode are presented in Table II.

TABLE II. The results of the experiments in the standard operating

Parameters	Values							
EMF, μW/cm^2	2.1	2.1	2.1	2.0	1.99	1.99	2	2.1
Time, s	15	30	45	60	75	90	105	120

According to the standards the level of electromagnetic field in the energy standard operating mode must be 2.0 μW/cm^2.

The maximum reletive error of the deviations less than 5 %, which according to the requisition to radio module.

To comply with the sanitary and hygienic standards of the World Health Organization (WHO) the density of electromagnetic field, which generated by extremely high-

frequency radiation of wireless module at a distance of 10 centimeters should be reduced by 2 times. [10].

The graph of the change of the density of the electromagnetic field with increasing distance to the source are presented in Figure 5.

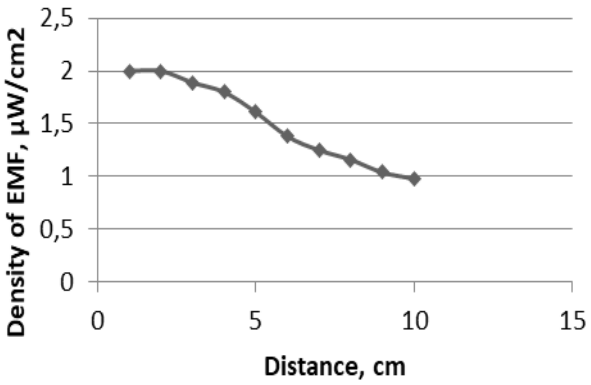

Fig. 5 The change density with increasing distance

According to the results, the density decreased by half which allows using this module, without additional shielding protection.

Results of experiments have showed that the relative error of common deviations of density of electromagnetic fields less than 6 % which according to the requisition to radio module nRF24L01. It was established that this module can be used without additional shielding protection in medical devices including portable spirometers.

Radio module nRF24L01 have passed all tests according to the IEEE Standartds 802.15 – IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture, IEEE 802.15g – IEEE Standard for Local and metropolitan area networks-- Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 3: Physical Layer (PHY) Specifications for Low-Data- Rate, Wireless, Smart Metering Utility, Std C95.1™-2005 – IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300GHz and it is recommended in equipping in telemedicine devices.

Radio module nRF24L01 can be used in medical devices because this module according to IEEE Standard Std C95.1™-2005 – IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300GHz.

REFERENCES

[1] http://www.who.int/en/.

[2] HTC S710 User Manual. High Tech Computer Corp. 2006. p. 2. Wi-Fi is a registered trademark of the Wireless Fidelity Alliance, Inc.Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[3] "2012 Global Losses From phishing Estimated At $1.5 Bn". FirstPost. 20 February 2013. Retrieved 21 December 2014.

[4] R. Tomashevskyi, V. Kulichenko, S. Batachenko, A. Poreva, O. Honcharenko, “Screening Diagnostic Systems for Chronic Obstructive Pulmonary Diseases”, 2016.

[5] C95.1-2005 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300GHz.

[6] Hankinson, JL; Odencrantz, JR; Fedan, KB (1999). "Spirometric reference values from a sample of the general U.S. population". American Journal of Respiratory and Critical Care Medicine. 159: 179–87

[7] Franconi, N. G.; Bunger, A; Sejdic, E; Mickle, M. H. (2014). "Wireless Communication in Oil and Gas Wells". Energy Technology. 2: 996–1005.

[8] http://printsip.ru/radioizmeritelnye-pribory/voltmetry/voltmetry-selektivnye-v6/item/v6-10

[9] Richard Feynman (1970). The Feynman Lectures on Physics Vol II. Addison Wesley Longman. ISBN 978-0-201-02115-8. A “field” is any physical quantity which takes on different values at different points in space.

[10] Schaum's outline of theory and problems of electromagnetics(2nd Edition), Joseph A. Edminister, McGraw-Hill, 2015.